

ELECTROOPTICAL DEVICE UTILIZING ELECTROPHORESIS

This is a Continuation-in-Part of Application No. 09/822,420 filed April 2, 2001. The entire disclosure of the prior application is hereby
5 incorporated by reference herein in its entirety.

BACKGROUND OF THE INVENTION

Field of technical art

The present invention relates to electrooptical devices utilizing
10 electrophoresis and, in particular, to electrooptical devices and electronic apparatuses capable of performing full color display with superior color reproducibility.

Description of related art

15 Japanese Patent publication No.49-32038 discloses a structure that consists of a pair of sheets, a porous spacer having a large number of pores and inserted between the sheets, and dispersion filled in each pore so as to be divided into minute areas. This publication explains that each divided area of dispersion provides a cell modulated in red, green or blue and these
20 cells are able to perform color display on the basis of the additive color process. The dispersion has a colored dispersion medium in which electrophoretic particles are dispersed. In actual production, an additive to control electrophoresis, such as a surface-active agent, is frequently included in the colored dispersion medium. However, for the sake of a
25 simplified explanation, the explanation of the additive will be omitted. It is therefore not meant that the dispersion medium of the present invention will not include the additive such as a surface-active agent. In working of the present invention into practice, a producer can decide whether or not the additive should be included in the colored dispersion medium, in

account of a material selected as the colored dispersion medium.

An electrophoretic display apparatus capable of altering, so some extent, brightness, chroma and hue has been realized so far. For example, an electrooptical device based on the electrophoresis is known, which is
 5 able to perform blue and white display using both white obtained from titanium oxide and blue obtained from a material of dye. However, practical materials of dispersion which permits given modulation required to produce color images have not been considered up to now.

10 BRIEF SUMMARY OF THE INVENTION

An object of the present invention is to provide an electrooptical device capable of performing display in multi-colors or the full colors.

To achieve this object, the present invention provides an electrooptical device comprising an electrooptical layer between electrodes,
 15 wherein the electrooptical layer includes a dispersion medium and particles (electrophoretic particles) contained in the dispersion medium, the particles are colored a first color and the dispersion medium is colored a second color, and the first color and the second color are related to each other based on a relationship of complementary colors. This apparatus will be
 20 referred to as a first electrooptical device.

In a preferred mode of this first electrooptical device, the first color is selected from a group including red, green and blue, and the second color is selected from a group including cyan, magenta and yellow.

The relationship between the colors of electrophoretic particles and
 25 the colors of dispersion mediums in the first electrooptical device will be exemplified as follows.

Table 1

Displayed color	R (red)	G (green)	B (blue)
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Colors of electro-

phoretic particles

R (red)

G (green)

B (blue)

Colors of dispersion

mediums

C (cyan)

M (magenta)

Y (yellow)

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According to the first electrooptical device, using colored dispersion mediums of which colors (CMY) are complementary to the colors of electro-optic particles enables the apparatus to have high intensity of color and high contrast, with both of the color density and a cell thickness kept to their minimums. Further, since the cell can be formed into a thinner one, the intensity of an electric field required for electrophoresis can be realized by lower applied voltage than the conventional voltage. Hence the voltage to drive the cell can be lowered markedly. Further, the thinner cell makes it possible to switch the cell ON/OFF at higher speed, which leads to display of dynamic images identical or superior to or than that performed with liquid crystal display.

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The present invention still provides an electrooptical device comprising an electrooptical layer between electrodes, wherein the electrooptical layer includes a dispersion medium and particles contained in the dispersion medium, and the particles are colored a first color and the dispersion medium is substantially colored black. This apparatus will be referred to as a second electrooptical device.

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In the second electrooptical device, it is preferred that the first color is selected from a group including red, green and blue.

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The relationship between the colors of particles and the colors of dispersion mediums in the second electrooptical device will be exemplified as follows.

Table 2

	Displayed color	R (red)	G (green)	B (blue)
	Colors of electro-phoretic particles	R (red)	G (green)	B (blue)
5	Colors of dispersion mediums	K (black)	K (black)	K (black)

According to the second electrooptical device, using the black-colored dispersion medium enables the apparatus to have high intensity of color and high contrast, with both of the color density and a cell thickness kept to their minimums. Further, since the cell can be formed into a thinner one, the intensity of an electric field required for electrophoresis can be realized by lower applied voltage than the conventional voltage. Hence the voltage to drive the cell can be lowered markedly. Further, the thinner cell makes it possible to switch the cell ON/OFF at higher speed, which leads to display of dynamic images identical or superior to or than that performed with liquid crystal display. Coloring of the dispersion medium can be done in common regardless of the colors of the particles, which is advantageous in production cost.

The present invention still provides an electrooptical device comprising an electrooptical layer between electrodes, wherein the electrooptical layer includes a dispersion medium and particles contained in the dispersion medium, the particles are colored a first color and the dispersion medium is colored a second color, and the second color is a color to absorb the first color. This apparatus will be referred to as a third electrooptical device.

In the third electrooptical device, it is preferred that the first color is selected from a group including red, green and blue.

The relationship between the colors of particles and the colors of dispersion mediums in the third electrooptical device will be exemplified as

follows.

Table 3

Displayed color	R (red)	G (green)	B (blue)
Colors of electro-			
phoretic particles	R (red)	G (green)	B (blue)
Colors of dispersion			
mediums	Kr (red	Kg (green	Kb (blue
	absorbed)	absorbed)	absorbed)

According to the third electrooptical device, using a colored dispersion medium that absorbs a color of electrophoretic particles enables the apparatus to have high intensity of color and high contrast, with both of the color density and a cell thickness kept to their minimums. Further, since the cell can be formed into a thinner one, the intensity of an electric field required for electrophoresis can be realized by lower applied voltage than the conventional voltage. Hence the voltage to drive the cell can be lowered markedly. Further, the thinner cell makes it possible to switch the cell ON/OFF at higher speed, which leads to display of dynamic images identical or superior to or than that performed with liquid crystal display. Limitations on coloring the dispersion medium are reduced as well, with the result that choice in materials of the dispersion medium is widened. Hence this makes it possible to improve characteristics of display.

The present invention still provides an electrooptical device comprising an electrooptical layer between electrodes, wherein the electrooptical layer has a plurality of cells each including a dispersion medium and particles contained in the dispersion medium, and the particles are colored differently from each other between the cells. This apparatus will be referred to as a fourth electrooptical device.

In the fourth electrooptical device, it is preferred to have a cell of which particles are colored red, a cell of which particles are colored green, and a cell of which particles are colored blue. In that case, the dispersion medium included in each cell may be substantially colored black, colored
5 so as to absorb a color of the particles included in the dispersion medium of each cell, or colored so as to be complementary to the particles included in the dispersion medium of each cell.

According to the fourth electrooptical device, high intensity of color and high contrast can be obtained, with both of the color density and a cell
10 thickness kept to their minimums. Further, voltage to drive the cell can be lowered markedly. Still, a thinner cell makes it possible to switch the cell ON/OFF at higher speed, which leads to full-color display of dynamic images identical or superior to or than that performed with liquid crystal display. Arbitrary two colors can be selected to combine with each other,
15 thereby providing multi-color display. The fourth electrooptical device can be used in any applications as the next-generation display that exceeds CRTs and liquid crystal displays.

The present invention still provides an electrooptical device comprising an electrooptical layer between electrodes, wherein the
20 electrooptical layer has a plurality of cells each including a dispersion medium and particles contained in the dispersion medium, and the plurality of cells form one pixel. This apparatus will be referred to as a fifth electrooptical device.

In the fifth electrooptical device, it is preferred that the particles are
25 colored differently from each other between the cells.

According to the fifth electrooptical device, high intensity of color and high contrast can be obtained, with both of the color density and a cell thickness kept to their minimums. Further, voltage to drive the cell can be lowered markedly. Still, a thinner cell makes it possible to switch the cell

ON/OFF at higher speed, which leads to full-color display of dynamic images identical or superior to or than that performed with liquid crystal display. Arbitrary two colors can be selected to combine with each other, thereby providing multi-color display. Coating microcapsules onto a flexible substrate is able to provide displays such as sheets of paper that exceed CRTs and liquid crystal displays.

The present invention is able to provide an electronic device in which the foregoing electrooptical device is incorporated as a display.

The present invention further provides an electrooptical device comprising electrodes which sandwich a plurality of micro-capsules, wherein, each of the micro-capsule contains a dispersion medium and a first particle and a second particle, the first particles are colored a first color and the second particles are are colored a second color, and the first color and the second color have a relationship that one is a complementary color of the other. This apparatus will be referred to as a sixth electrooptical device.

In the sixth electrooptical device, it is preferred that the first color is selected from a group including red, green and blue, and the second color is selected from a group including cyan, magenta and yellow.

The present invention further provides an electrooptical device comprising: a cell containing a plurality of microcapsules which contains a dispersion medium, a first particle with a first color and a second particle with a second color; and electrodes which sandwich the cell; wherein the first color and the second color have a relationship that one is a complementary color of the other. This apparatus will be referred to as a seventh electrooptical device.

In the electronic device of the present invention, the employment of any one of the first to seventh electrooptical devices as a display realizes thin type of displays of which display performance is close to printed

matters, which has been one ideal of electronic displays.

In the electrooptical device according to the present invention or the electronic devices using the same, the color of particles (electrophoretic particles) may be either the color of their core material or the color of their coating material. The present invention does not intend limiting the detailed structures and specifications of the coloring.

By way of example, iron oxide may be selected as red (R) particles, cobalt green as green (G) particles, and cobalt blue as blue (B) particles. Many other materials are also available, which are disclosed by Japanese Patent publication No.50-15115, so details about them are omitted here.

The color of the dispersion medium may be realized by the color of its material itself or the color of dye. Alternatively, pigment that does not affect electrophoretic particles may be used as the dispersion medium. The present invention does not intend limiting the detailed structures and specifications of the coloring. By way of example, selectable is pigment having an azo group ($-N=N-$) or an anthraquinone structure and having a color of cyan, magenta, yellow or black.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig.1 is a sectional view of an electrophoretic display cell according to the present invention when displaying brightly.

Fig.2 is a sectional view of the electrophoretic display cell according to the present invention when displaying darkly.

Fig.3 is a sectional view of an electrophoretic display cell according to another embodiment of the present invention, in which red electrophoretic particles are combined with a cyan-colored dispersion medium, when displaying brightly.

Fig.4 is a sectional view of the electrophoretic display cell according to the embodiment of the present invention, in which red

electrophoretic particles are combined with a cyan-colored dispersion medium, when displaying darkly.

Fig.5 is a sectional view of an electrophoretic display cell according to another embodiment of the present invention, in which green

5 electrophoretic particles are combined with a magenta-colored dispersion medium, when displaying brightly.

Fig.6 is a sectional view of the electrophoretic display cell according to the embodiment of the present invention, in which green electrophoretic particles are combined with a magenta-colored dispersion
10 medium, when displaying darkly.

Fig.7 is a sectional view of an electrophoretic display cell according to another embodiment of the present invention, in which blue electrophoretic particles are combined with a yellow-colored dispersion medium, when displaying brightly.

15 Fig.8 is a sectional view of the electrophoretic display cell according to the embodiment of the present invention, in which blue electrophoretic particles are combined with a yellow-colored dispersion medium, when displaying darkly.

Fig.9 is a sectional view of an electrophoretic display cell according
20 to another embodiment of the present invention, in which red electrophoretic particles are combined with a black-colored dispersion medium, when displaying brightly.

Fig.10 is a sectional view of the electrophoretic display cell according to the embodiment of the present invention, in which red
25 electrophoretic particles are combined with a black-colored dispersion medium, when displaying darkly.

Fig.11 is a sectional view of an electrophoretic display cell according to another embodiment of the present invention, in which green electrophoretic particles are combined with a black-colored dispersion

medium, when displaying brightly.

Fig.12 is a sectional view of the electrophoretic display cell according to the embodiment of the present invention, in which green electrophoretic particles are combined with a black-colored dispersion medium, when displaying darkly.

Fig.13 is a sectional view of an electrophoretic display cell according to another embodiment of the present invention, in which blue electrophoretic particles are combined with a black-colored dispersion medium, when displaying brightly.

Fig.14 is a sectional view of the electrophoretic display cell according to the embodiment of the present invention, in which blue electrophoretic particles are combined with a black-colored dispersion medium, when displaying darkly.

Fig.15 is a sectional view of an electrophoretic display cell according to another embodiment of the present invention, in which red electrophoretic particles are combined with a colored dispersion medium made so as to absorb at least a component of red, when displaying brightly.

Fig.16 is a sectional view of the electrophoretic display cell according to the embodiment of the present invention, in which red electrophoretic particles are combined with a colored dispersion medium made so as to absorb at least a component of red, when displaying darkly.

Fig.17 is a sectional view of an electrophoretic display cell according to another embodiment of the present invention, in which green electrophoretic particles are combined with a colored dispersion medium made so as to absorb at least a component of green, when displaying brightly.

Fig.18 is a sectional view of the electrophoretic display cell according to the embodiment of the present invention, in which green electrophoretic particles are combined with a colored dispersion medium

made so as to absorb at least a component of green, when displaying darkly.

Fig.19 is a sectional view of an electrophoretic display cell according to another embodiment of the present invention, in which blue
5 electrophoretic particles are combined with a colored dispersion medium made so as to absorb at least a component of blue, when displaying brightly.

Fig.20 is a sectional view of the electrophoretic display cell according to the embodiment of the present invention, in which blue
10 electrophoretic particles are combined with a colored dispersion medium made so as to absorb at least a component of blue, when displaying darkly.

Fig.21 is a sectional view of an electrophoretic display microcapsule according to another embodiment of the present invention, in which red electrophoretic particles are combined with a black-colored
15 dispersion medium, when displaying brightly.

Fig.22 is a sectional view of the electrophoretic display microcapsule according to another embodiment of the present invention, in which red electrophoretic particles are combined with a black-colored dispersion medium, when displaying darkly.

20 Fig.23 is a plan view of a full-color electrophoretic display apparatus in which RGB display cells according to another embodiment of the present invention are juxtaposed.

Fig.24 is a plan view of a full-color electrophoretic display apparatus in which electrophoretic display microcapsules according to
25 another embodiment of the present invention are juxtaposed in RGB display cells.

Fig. 25 is a sectional view of an electrophoretic display microcapsule according to another embodiment of the present invention, where a microcapsule contains two types of electrophoretic particles.

Fig. 26 is a sectional view of the electrophoretic display microcapsule according to another embodiment of the present invention, where a microcapsule contains two types of electrophoretic particles.

5 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the accompanying drawings, the present invention will now be described.

Figs.1 and 2 are sectional views of a cell (CELL) for performing electrophoretic display. For the sake of simplified explanation, the
10 illustration of detailed constituents, such as electrodes and a bulkhead, are omitted. In the figures, a reference P shows electrophoretic particles, a reference L shows a colored dispersion medium, and a reference S shows dispersion containing both electrophoretic particles and dispersion medium. It is frequent that an actual cell additionally uses an additive such as a
15 surface-active agent, but this is omitted in the embodiment. As to the additive, addition or non-addition thereof is arbitrary and any type is selectable. First a fundamental operation will be explained. When applied voltage to the cell causes the electrophoretic particles P to migrate to a user-viewing-side electrode, the state shown in Fig.1 is realized. In
20 this case, a viewer is able to directly see the electrophoretic particles P, so that the viewer can recognize the external color of the particles P. This state is referred to as “bright” or “ON.” On the other hand, when the electrophoretic particles P migrate to an opposite electrode to the user, the state shown in Fig.2 is realized, where a viewer can recognize a certain
25 color that has experienced the absorption of a color component through the colored dispersion medium L. This state is referred to as “dark” or “OFF.” Although the cell is depicted to have a rectangular section, its shape is not limited to a rectangle, but any shape of the section can be applied to the present invention. Microcapsules described in the claims

are also applied to the present invention. An intention of the present invention is combinations of colors of dispersion, which will be explained in detail.

Through incidence light used actually contains various wavelength components, a very simple model is representatively explained for the sake of description of the present invention. However, the present invention is not confined to only such a theoretical model, and it is also applied to the cell used in usual environments (outdoors during the daytime, lighted indoor environments, or others).

Incidence light consists of the three primary colors of blue (B), red (R) and green (G). Concerning the wavelength, the blue (B) is approximately 380 nm, the red (R) is approximately 780 nm, and the green (G) is approximately 520 nm, respectively. The incidence light can I can be decomposed into intensities (I_r , I_g , I_b) of the wavelengths of the three primary colors, of which decomposition is expressed by the following formula.

$$I = I_r + I_g + I_b \quad \dots (1)$$

Reflection brightness (I_{refon}) for being bright (ON) is determined by the reflectance (R_r , R_g , R_b) of each color component, and expressed by the following formula.

$$I_{refon} = (I_r + I_g + I_b) \cdot (R_r + R_g + R_b) \quad \dots (2)$$

In contrast, reflection brightness ($I_{reffoff}$) for being dark (OFF) is determined by the reflectance of each component and the transmittance (T_r , T_g , T_b) of each dispersion medium to each color, which will be expressed by the following formula.

$$I_{reffoff} = (I_r + I_g + I_b) \cdot (R_r + R_g + R_b) \cdot (T_r^2 + T_g^2 + T_b^2) \quad \dots (3)$$

The inventor of the present invention has devised how to control each component of the R, G and B colors independently with the foregoing formulas (1), (2) and (3) kept true.

That is, the reflection brightness for being bright (ON) is understood as follows if each color is controlled independently. In the case of a cell displaying R (red), it is understood that, from the formula (2), only the reflectance R_r that reflects the component R is effective and the reflectance (R_g, R_b) of the remaining components is required to be zero or close to zero. Similarly, in the case of a cell displaying G (green), it is understood that, from the formula (2), only the reflectance R_g that reflects the component G is effective and the reflectance (R_r, R_b) of the remaining components is required to be zero or close to zero. Similarly, in the case of a cell displaying B (blue), it is understood that, from the formula (2), only the reflectance R_b that reflects the component B is effective and the reflectance (R_r, R_g) of the remaining components is required to be zero or close to zero. Elements in charge of the reflection are electrophoretic particles, and this results in the necessity that the electrophoretic particles reflect the colors R, G and B.

On the other hand, the reflection brightness for being dark (OFF) is based on the fact that incidence light is absorbed during passing a dispersion medium at a rate dependent on a colored density and a thickness of the medium. Where a cell displays R (red), it is understood that, from the formula (3), only the transmittance T_r that transmits the component R is effective but the transmittance (T_g, T_b) of the remaining components is not effective. Similarly, where a cell displays G (green), it is understood that, from the formula (3), only the transmittance T_g that transmits the component G is effective but the transmittance (T_r, T_b) of the remaining components is not effective. Similarly, where a cell displays B (blue), it is understood that, from the formula (3), only the transmittance T_b that transmits the component B is effective but the transmittance (T_r, T_g) of the remaining components is not effective. An Element to determine the transmittance is a colored dispersion medium, so that it is understood for

the colored dispersion mediums that the transmittance of the colors corresponding to the electrophoretic particles of at least red (R), green (G) and blue (B) are fundamental elements to control modulation. In other words, main members for modulation are colored dispersion mediums of cyan (C), magenta (M) and yellow (Y) that are complementary colors to red (R), green (G) and blue (B), a black (K) dispersion medium capable of absorbing all the components, or colored dispersion mediums to which Kr, Kg and Kb are colored, the Kr, Kg and Kb being capable of absorbing at minimum R, G and B reflected by the electrophoretic particles.

Various embodiments of electrooptical devices according to the present invention will now be described.

A. First embodiment

Figs.3 and 4 show sectional views of a cell for display of red (R).

Although one display panel is composed of a plurality of such cells, constituents such as electrodes and a bulkhead are omitted from being depicted for the sake of simplified explanation. Electrophoretic particles

Pr have a characteristic of reflecting the component of red (R). A

dispersion medium (Lc) is colored cyan (C) to absorb the wavelength component of the red (R). When applied voltage causes the

electrophoretic particles Pr to migrate to an electrode located to the user side, a state shown in Fig.3 is realized. In this case, the electrophoretic particles Pr can be seen directly by the user, where the red is displayed brightly. On the other hand, when the electrophoretic particles migrate to the electrode opposite to the user, a state shown in Fig.4 is provided. In

this situation, incidence light is subject to absorption of the colored dispersion medium (Lc), reflected by the electrophoretic particles Pr, then again subject to absorption of the colored dispersion medium (Lc), thereby a dark red or black being displayed. Although the cell is depicted to have a rectangular section, its shape is not limited to a rectangle, but any shape

of the section can be applied to the present invention. An intention of the present invention is combinations of colors of dispersion.

Figs.5 and 6 show sectional views of a cell for display of green (G). For the sake of simplified explanation, constituents such as electrodes and a bulkhead are omitted from being depicted in detail. Electrophoretic particles Pg have a characteristic of reflecting the component of green (G). A dispersion medium (Lm) is colored magenta (M) to absorb the wavelength component of the green (G). When applied voltage causes the electrophoretic particles Pg to migrate to an electrode located at the user side, a state shown in Fig.5 is realized. In this case, the electrophoretic particles Pg can be seen directly by the user, where the green is displayed brightly. On the other hand, when the electrophoretic particles migrate to the electrode opposite to the user, a state shown in Fig.6 is provided. In this case, the cell is displayed in a dark green or black, because the incidence light experiences the absorption of the colored dispersion medium (Lm).

Figs.7 and 8 show sectional views of a cell for display of blue (B). For the sake of simplified explanation, constituents such as electrodes and a bulkhead are omitted from being depicted in detail. Electrophoretic particles Pb have a characteristic of reflecting the component of blue (B). A dispersion medium (Ly) is colored yellow (Y) to absorb the wavelength component of the blue (B). When applied voltage causes the electrophoretic particles Pb to migrate to an electrode located at the user side, a state shown in Fig.7 is realized. In this case, the electrophoretic particles Pb can be seen directly by the user, where the blue is displayed brightly. On the other hand, when the electrophoretic particles migrate to the electrode opposite to the user, a state shown in Fig.8 is provided. In this case, the cell is displayed in a dark blue or black, because the incidence light experiences the absorption of the colored dispersion medium (Ly).

Therefore, using both the three primary colors (RGB) of electrophoretic particles and their complementary colors (CMY) of dispersion mediums enables the cells to have high intensity of color and high contrast, with both of the color density and the cell thickness kept to their minimums. Further, since the cell can be formed into a thinner one, the intensity of an electric field required for electrophoresis can be realized by lower applied voltage than the conventional voltage. Hence the voltage to drive the cell can be lowered markedly. Further, the thinner cell makes it possible to switch the cell ON/OFF at higher speed, which leads to display of dynamic images identical or superior to or than that performed with liquid crystal display.

B. Second embodiment

Figs.9 and 10 show sectional views of a cell for display of red (R). For the sake of simplified explanation, constituents such as electrodes and a bulkhead are omitted from being depicted. Electrophoretic particles Pr have a characteristic of reflecting the component of red (R). A dispersion medium (Lk) is colored black. When applied voltage causes the electrophoretic particles Pr to migrate to an electrode located at the user side, a state shown in Fig.9 is realized. In this case, the electrophoretic particles Pr can be seen directly by the user, where a bright red is displayed. On the other hand, when the electrophoretic particles migrate to the electrode opposite to the user, a state shown in Fig.10 is provided. In this case, the cell is displayed in a dark red or black, because the incidence light experiences the absorption of the colored dispersion medium (Lk). Although the cell is depicted to have a rectangular section, its shape is not limited to a rectangle, but any shape of the section can be applied to the present invention. An intention of the present invention is combinations of colors of dispersion.

Figs.11 and 12 show sectional views of a cell for display of green

(G). For the sake of simplified explanation, constituents such as electrodes and a bulkhead are omitted from being depicted. When applied voltage causes electrophoretic particles Pg to migrate to an electrode located at the user side, a state shown in Fig.11 is realized. In this case, the electrophoretic particles Pg can be seen directly by the user, where a bright green is displayed. On the other hand, when the electrophoretic particles migrate to the electrode opposite to the user, a state shown in Fig.12 is provided. In this case, the cell is displayed in a dark green or black, because the incidence light experiences the absorption of the colored dispersion medium (Lk).

Figs.13 and 14 show sectional views of a cell for display of blue (B). For the sake of simplified explanation, constituents such as electrodes and a bulkhead are omitted from being depicted. When applied voltage causes electrophoretic particles Pb to migrate to an electrode located at the user side, a state shown in Fig.13 is realized. In this case, the electrophoretic particles Pb can be seen directly by the user, where a bright blue is displayed. On the other hand, when the electrophoretic particles migrate to the electrode opposite to the user, a state shown in Fig.14 is provided. In this case, the cell is displayed in a dark blue or black, because the incidence light experiences the absorption of the colored dispersion medium (Lk).

Therefore, using both the three primary colors (RGB) of electrophoretic particles and a black-colored dispersion medium enables the cells to have high intensity of color and high contrast, with both of the color density and the cell thickness kept to their minimums. Further, since the cell can be formed into a thinner one, the intensity of an electric field required for electrophoresis can be realized by lower applied voltage than the conventional voltage. Hence the voltage to drive the cell can be lowered markedly. Further, the thinner cell makes it possible to switch the

cell ON/OFF at higher speed, which leads to display of dynamic images identical or superior to or than that performed with liquid crystal display.

C. Third embodiment

Figs.15 and 16 show sectional views of a cell for display of red (R).

5 For the sake of simplified explanation, constituents such as electrodes and a bulkhead are omitted from being depicted. Electrophoretic particles Pr have a characteristic of reflecting the component of red (R). A dispersion medium (Lkr) is colored so as to absorb at least a wavelength component of the red (R). When applied voltage causes the electrophoretic particles Pr
10 to migrate to an electrode located at the user side, a state shown in Fig.15 is realized. In this case, the electrophoretic particles Pr can be seen directly by the user, where a bright red is displayed. On the other hand, when the electrophoretic particles migrate to the electrode opposite to the user, a state shown in Fig.16 is provided. In this case, the cell is displayed in a
15 dark red or black, because the incidence light experiences the absorption of the colored dispersion medium (Lkr). Although the cell is depicted to have a rectangular section, its shape is not limited to a rectangle, but any shape of the section can be applied to the present invention. An intention of the present invention is combinations of colors of dispersion.

20 Figs.17 and 18 show sectional views of a cell for display of green (G). For the sake of simplified explanation, constituents such as electrodes and a bulkhead are omitted from being depicted. Electrophoretic particles Pg have a characteristic of reflecting a wavelength component of green (G). A colored dispersion medium (Lkg) is colored
25 so as to absorb at least the component of the green (G). When applied voltage causes the electrophoretic particles Pg to migrate to an electrode located at the user side, a state shown in Fig.17 is realized. In this case, the electrophoretic particles Pg can be seen directly by the user, where a bright green is displayed. On the other hand, when the electrophoretic

particles migrate to the electrode opposite to the user, a state shown in Fig.18 is provided. In this case, the cell is displayed in a dark green or black, because the incidence light experiences the absorption of the colored dispersion medium (Lkg).

5 Figs.19 and 20 show sectional views of a cell for display of blue (B). For the sake of simplified explanation, constituents such as electrodes and a bulkhead are omitted from being depicted. Electrophoretic particles Pb have a characteristic of reflecting a wavelength component of blue (B). A dispersion medium (Lkb) is colored so as to absorb at least the component
10 of the blue (B). When applied voltage causes the electrophoretic particles Pb to migrate to an electrode located at the user side, a state shown in Fig.19 is realized. In this case, the electrophoretic particles Pb can be seen directly by the user, where a bright blue is displayed. On the other hand, when the electrophoretic particles migrate to the electrode opposite to
15 the user, a state shown in Fig.20 is provided. In this case, the cell is displayed in a dark blue or black, because the incidence light experiences the absorption of the colored dispersion medium (Lkb).

Therefore, using both the electrophoretic particles of the three primary colors (RGB) and a colored dispersion medium colored to absorb
20 at least designated one of the three primary colors enables the cells to have high intensity of color and high contrast, with both of the color density and the cell thickness kept to their minimums. Further, since the cell can be formed into a thinner one, the intensity of an electric field required for electrophoresis can be realized by lower applied voltage than the
25 conventional voltage. Hence the voltage to drive the cell can be lowered markedly. Further, the thinner cell makes it possible to switch the cell ON/OFF at higher speed, which leads to display of dynamic images identical or superior to or than that performed with liquid crystal display.

D. Fourth embodiment

Figs.21 and 22 show sectional views of a microcapsule (CAPS) for display of red (R). For the sake of simplified explanation, constituents such as electrodes and a bulkhead are omitted from being depicted.

When applied voltage causes the electrophoretic particles Pr to migrate to an electrode located at the user side, a state shown in Fig.21 is realized.

In this case, the electrophoretic particles Pr can be seen directly by the user, where a bright red is displayed. On the other hand, when the

electrophoretic particles migrate to the electrode opposite to the user, a state shown in Fig.22 is provided. In this case, the cell is displayed in a dark red or black, because the incidence light experiences the absorption of the colored dispersion medium (Lk). Although the microcapsule is depicted to have a circular section, its shape is not limited to a circle, but any shape of the section can be applied to the present invention. An intention of the present invention is combinations of colors of dispersion.

For displaying the green (G) or blue (B), the constituents of the microcapsule may be selected in a similar manner to the foregoing first to third embodiments.

Therefore, using both electrophoretic particles of the three primary colors (RGB) and a dispersion medium colored black, a complementary colored dispersion medium, or a colored dispersion medium colored to absorb at least designated one of the three primary colors enables the cells to have high intensity of color and high contrast, with both of the color density and the microcapsule size kept to their minimums. Further, since the microcapsule can be formed into a compact one, the intensity of an electric field required for electrophoresis can be realized by lower applied voltage than the conventional voltage. Hence the voltage to drive the microcapsule can be lowered markedly. Further, the compact microcapsule makes it possible to switch the microcapsule ON/OFF at higher speed, which leads to display of dynamic images identical or

superior to or than that performed with liquid crystal display.

E. Fifth embodiment

Fig.23 is a plan view showing a plurality of juxtaposed RGB cells.

The three types of dispersion Sr, Sg and Sb described by the foregoing first
5 to third embodiments are juxtaposed to compose one pixel. An actual cell
needs constituents, such as driving elements and driving electrodes, to send
signals of pixel information, but those constituents are omitted from being
drawn, so that the illustration is simplified. This embodiment adopts the
RGB cells arranged side by side, but those cells may be arranged in a delta
10 shape or others. In the present invention, how to arrange the cells is not
restricted, so that the three primary colors may be arranged in any form.
In Fig.23, dashed lines exhibit pixels, which are continuously arranged.
Each of the cells CELL (R), CELL (G) and CELL (B) is composed by the
dispersion described in the foregoing first, second or third embodiment.
15 Hence, arbitrary switching control of the RGB cells enables display in the
full colors.

Therefore, juxtaposing the cells each of which uses both
electrophoretic particles of the three primary colors (RGB) and a dispersion
medium colored black, a complementary colored dispersion medium, or a
20 colored dispersion medium colored to absorb at least designated one of the
three primary colors enables the cells to have high intensity of color and
high contrast, with both of the color density and the cell thickness kept to
their minimums. Further, the voltage to drive the cell can be lowered
markedly. Further, the thinner cell makes it possible to switch the cell
25 ON/OFF at higher speed, which leads to display of dynamic images
identical or superior to or than that performed with liquid crystal display.

If using multi-colors, any two colors are selectable and combined
with each other.

F. Sixth embodiment

Fig.24 is a plan view showing a plurality of juxtaposed RGB cells. The three types of dispersion Sr, Sg and Sb described by the foregoing first to third embodiments are individually filled into a microcapsule CAPS and a plurality of microcapsules of the same color are formed into each cell

5 CELL (R), CELL (G) or CELL (B). The three cells are juxtaposed to form one pixel. Actual cells need constituents, such as driving elements and driving electrodes, to send signals of pixel information, but those constituents are omitted from being drawn, so that the illustration is simplified. For the sake of a further simplified illustration, structural

10 members including binder to secure the capsule are also omitted from being depicted. This embodiment adopts the RGB cells arranged side by side, but those cells may be arranged in a delta shape or others. In the present invention, how to arrange the cells is not restricted, so that the three primary colors may be arranged in any form. In Fig.24, dashed lines

15 exhibit pixels, which are continuously arranged. The microcapsule CAPS included by each of the cells CELL (R), CELL (G) and CELL (B) is composed by the dispersion described in the foregoing first, second or third embodiment. Hence, arbitrary switching control of the RGB cells enables display in the full colors. Therefore, juxtaposing the microcapsules each

20 of which uses both electrophoretic particles of the three primary colors (RGB) and a dispersion medium colored black, a complementary colored dispersion medium, or a colored dispersion medium colored to absorb at least designated one of the three primary colors enables the cells to have high intensity of color and high contrast, with both of the color density and

25 the cell thickness kept to their minimums. Further, the voltage to drive the cell can be lowered markedly. Further, the thinner cell makes it possible to switch the cell ON/OFF at higher speed, which leads to display of dynamic images identical or superior to or than that performed with liquid crystal display. If using multi-colors, any two colors are selectable

and combined with each other.

G. Seventh Embodiment

Figs. 25 and 26 show sectional views of a microcapsule (CAPS) which contains two types of electrophoresis particles. In an actual
 5 product, a plurality of microcapsules make up a display panel. However, to make the explanation simpler, Figs. 25 and 26 show only one microcapsule. Also, other parts of the display panel such as electrodes or binders are not shown in Figs. 25 and 26. As shown in Figs. 25 and 26, the microcapsule contains a dispersion medium L, a first electrophoresis
 10 particle P1, and a second electrophoresis particle P2. The electrophoresis particle P1 carries a positive charge, and the second electrophoresis particle P2 carries a negative charge. Also, the relation of the colors between the first electrophoresis particle P1 and the second electrophoresis particle P2 is complementary color. Namely, when the color of the first
 15 electrophoresis particle P1 is red (R), the color of the second electrophoresis particle P2 is cyan (C); when the color of the first electrophoresis particle P1 is green (G), the color of the second electrophoresis particle P2 is magenta (M); when the color of the first electrophoresis particle P1 is blue (B), the color of the second
 20 electrophoresis particle P2 is yellow (Y). The dispersion medium L is transparent.

When negative voltage is applied to an electrode (not shown) located at the user side (the eyes shown in Figs. 25 and 26 indicate the user's eyes), the first electrophoresis particle P1 migrates to the electrode at
 25 the user side, and the second electrophoresis particle P2 migrates to the other side as shown in Fig. 25. By this, the color of the electrophoresis P1 can be seen by the user. On the other hand, when positive voltage is applied to an electrode (not shown) located at the user side, the second electrophoresis particle P2 migrates to the electrode at the user side, and the

first electrophoresis particle P1 migrates to the other side as shown in Fig.

26. By this, the color of the electrophoresis P2 can be seen by the user.

Using the relationship of the complementary color between the first electrophoresis particle and the second electrophoresis particle, it becomes

5 possible to obtain excellent color purity and high contrast even when the colored densities of the first electrophoresis particle and the second electrophoresis particle are minimum and the cell thickness is minimum.

Also, in the same manner as the sixth embodiment, it is possible to realize full color. That is, as shown in Fig. 24, microcapsules according to this

10 embodiment are put in cells based on their colors of red (G), green (G), and blue (B), and three cells of RGB form one pixel for full color.